ADDENDUM TO

"DEPLETED URANIUM AND VETERANS HEALTH: A FLAWED TESTING PROCESS AND AN UNDERSIZED, POLITICIZED STUDY LIMIT EVALUATION OF EXPOSURES AND EFFECTS"

Dan Fahey

Institute of Medicine
Washington, DC

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The following tables and narrative contain additional information about recommended limits on intake, exposure estimates, tumor formation, and Hodgkin's lymphoma. This information supplements my Power Point presentation to the Institute of Medicine, and is excerpted from:

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Table 1. Recommended limits on intake

	United States	Others
Members of the Public	0.05 mg/15 minutes[1] 0.5 mg/day[2]	0.035 mg/day[3] 4.5 mg/year[4]
Occupational Workers	0.18 mg/15 minutes[5] 2 mg/day[6] 10mg/week[7] 480 mg/year[8]	0.18 mg/15 minutes[9] 2 mg/day[10] 130 mg/year[11]

Table compiled by Dan Fahey

The recommended limits on intake provide a basis from which to assess the significance of theoretical exposure estimates in a range of battlefield scenarios (Table 2). The Royal Society has generated a series of estimates intended to be generic for soldiers and civilians in conflicts where DU munitions are used.[12] In 1999, the U.S. Army Center for Health Promotion and Preventive Medicine developed a set of exposure estimates that were subsequently criticized as "incomplete and misleading" by the Presidential Special Oversight Board on Gulf War Veterans' Illnesses.[13] Consequently, the Army undertook a series of live-fire tests of DU rounds, known as the Capstone Project, and released revised estimates in 2004 (figures listed below are the Capstone estimates).[14] In 2005, Sandia National Laboratories (U.S.) published a study that included exposure estimates. The Royal Society, U.S. Army, and Sandia estimates are similar in some cases; in others they vary by orders of magnitude.

Table 2. Estimated intakes in exposure scenarios, durations of exposure

	Royal Society "Central" Estimate [15] (Time)	Royal Society "Worst-Case" Estimate [16] (Time)	U.S. Army "Most Likely" Estimate[17] (Time)	U.S. Army "Upper Bound" Estimate[18] (Time)	Sandia "Nominal Exposure"[19] (No duration specified)	Sandia "Maximum Exposure"[20] (No duration specified)
Soldiers in an armored vehicle penetrated by a DU round	250 mg (1 minute)	5000 mg (1 hour)	10-280 mg (1 minute) 43-710 mg (5 minutes)	91-970 mg (1 hour) 110-1000 mg (2 hours)	250 mg *inhalation* 330 mg *fragments* 15 mg *ingestion*	4000 mg *inhalation* 1800 mg *fragments* 500 mg *ingestion*
Soldiers who enter vehicles to rescue occupants immediately after a DU impact	250 mg (1 minute)	5000 mg (1 hour)	27-200 mg (10 minutes)	No estimate	250 mg *inhalation* 15 mg *ingestion*	4000 mg *inhalation* 500 mg *ingestion*
People who work in and around DU-impacted equipment	1 mg *inhalation* 0.5 mg *ingestion* (1 hour)	200 mg *inhalation* 50 mg *ingestion* (10 hours)	0.45 mg *inhalation* 10.6 mg *Ingestion* (1 hour)	14.5 mg *inhalation* 10.6 mg *ingestion* (1 hour)	40 mg *inhalation* 30 mg *ingestion*	600 mg *inhalation* 300 mg *ingestion*
Child at play	No estimate	No estimate	No estimate	No estimate	54 mg *inhalation* 3000 mg *ingestion*	226 mg *inhalation* 9000 mg *ingestion*
People downwind of DU-impacts	0.07 *inhalation* (passage of plume)	4.9 mg *inhalation* (passage of plume)	0.00006 mg *inhalation* (passage of plume)	0.04 mg *inhalation* (passage of plume)	0.003 mg *inhalation*	0.1 mg *inhalation*
Inhalation of resuspended DU from soil	0.8 mg[21] (27 days)	80 mg[22] (27 days)	No estimate	No estimate	0.001 mg *inhalation*	0.003 mg *inhalation*

Table compiled by Dan Fahey

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5.1 **Cancer**

Laboratory studies have clearly demonstrated that DU is carcinogenic, but the link between DU and cancer in humans remains uncertain. Some of the uncertainties are related to the long latency period for development of cancers related to DU and the fact that few exposed humans have been studied. While the use of DU munitions appears unlikely to cause widespread cancers, sufficient evidence exists to support concerns that exposure to DU may lead to an elevated risk of cancer in heavily exposed populations.

5.1.1 *Laboratory studies*

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[TUMOR FORMATION]

Research conducted by the US Armed Forces Radiobiology Research Institute (AFRRI) found that DU transformed human cells to a pre-cancerous phase; these cells then produced tumors when they were injected into mice.[23] The transformed cells also induced genetic instability and reduced production of a key tumor-suppressor protein.[24]

Other AFRRI studies found that DU causes DNA damage that might initiate and promote the formation of tumors.[25] The damage to DNA appears to be caused by both alpha radiation and chemical effects,[26] with delayed chromosomal damage observed in cells not directly irradiated by DU (the so-called "bystander effect").[27] "Considering that conventional understanding of potential DU health effects assumes that chemical effects are of greatest concern, results demonstrating that both radiation and chemical effects are involved in DU-induced cellular damage could have a significant impact on DU risk assessments."[28]

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5.1.3.1 *Hodgkin's Lymphoma*

The one cancer that has repeatedly shown up in surveys of veterans is Hodgkin's lymphoma (also known as Hodgkin's disease). Hodgkin's lymphoma develops in the lymph nodes, and it is a rare form of cancer (2.58 cases per 100,000 people in more developed countries; 0.94 cases per 100,000 in less developed countries[29]) with no known risk factor.[30] According to the Institute of Medicine:

> "The lymphatic system is an important potential target for uranium radiation because inhaled insoluble uranium oxides can remain up to several years in the hilar lymph nodes of the lung. Studying the effect of uranium exposure on lymphatic cancer is more difficult than studying lung cancer because lymphatic cancer is much less common."[31]

In general, Hodgkin's lymphoma occurs more often among men and in people aged 15-34 and over 55.

In the United States, one out of 50 veterans examined in 1999 by the Department of Veterans Affairs" DU Program had Hodgkin's lymphoma.[32] It is worth noting that although this cancer was first reported in 1999 and discussed during an October 1999 meeting between the doctor in charge of the study and several Pentagon officials, in January 2001 a Pentagon official publicly denied the existence of this or any cancer among US veterans in the DU study.[33]

In August 2002, the UK Ministry of Defence released a study showing that deaths due to lymphatic cancers were nearly twice as high among Gulf War veterans compared to a control group.[34] There is no publicly available information about the number of cases of Hodgkin's lymphoma versus the more-common Non-Hodgkin's lymphoma, but of the 3,172 Gulf veterans seen at the UK Gulf Veterans" Medical Assessment Programme as of 31 January 2003, 11 cases of lymphoma (including Hodgkin's and Non-Hodgkin's) had been reported.[35] The Ministry of Defence denies a link between these cancers and DU, but has initiated an additional study to clarify this finding.

Among Italian soldiers who served in Bosnia and/or Kosovo, "there is a disproportionately high number, which is statistically significant, of cases of Hodgkin's Lymphoma."[36] Although the Italian Defense Ministry could not identify the causes of this increase, it stated: “The results of sample studies carried out on Italian soldiers on duty in Bosnia and Kosovo have not shown evidence of depleted uranium contamination.”[37] Overall, the Defense Ministry found a smaller-than-expected number of cancer cases among these soldiers.[38]

Endnotes

[1] This limit is for inhalation of insoluble uranium based on a short-term exposure limit of 0.15 mg/m³ based on a breathing rate of 9.6 m³ per eight-hour working day. US National Institute for Occupational Safety and Health (NIOSH), “Pocket Guide to Chemical Hazards,” 1994; see also United Nations Environment Programme, “Depleted Uranium in Bosnia and Herzegovina.” (Geneva: UNEP, 25 March 2003) p. 261.

[2] This limit is for inhalation of insoluble uranium based on chronic exposure limit of 0.05 mg/m³ based on a breathing rate of 9.6 m³ per eight-hour working day. NIOSH *supra* n. 107; see also United Nations Environment Programme, “Depleted Uranium in Bosnia and Herzegovina.” (Geneva: UNEP, 25 March 2003) p. 261. Another reference states that the limit for inhalation of DU for members of the public equates to breathing a mass of 0.2 mg/day; R.L. Fliszar, “Radiological Contamination from Impacted Abrams Heavy Armor,” Technical Report BRL-TR-3068 (Aberdeen Proving Ground, MD, Ballistic Research Laboratory December 1989) p. 18.

[3] The International Commission on Radiological Protection and the World Health Organization prescribe slightly different limits on intake by inhalation for members of the public, based partly on differences in limits based on chemical toxicity and radiation dose. To resolve this discrepancy, a recommendation has been made “that a unified…daily intake of 35 [micrograms] would be acceptable in most cases. This value would satisfy the constraints imposed by radiation dose and chemical toxicity. However, for protracted exposure to highly insoluble uranium compounds, a further three-fold reduction may be considered appropriate.” N. Stradling et al, “Anomalies between radiological and chemical limits for uranium after inhalation by workers and the public,” 105 *Radiation Protection Dosimetry* (2003) 178.

[4] This refers to an inhalation of type S (insoluble) natural uranium and is based on a 1 micron activity mean aerodynamic diameter (AMAD). As noted above (see supra n. 8), the majority of DU particles created by an impact are insoluble. The limit for intake by inhalation of type M (moderately soluble) natural uranium is 13 mg/year; for type F (soluble) it is 75 mg/year. N. Stradling et al, “Anomalies between radiological and chemical limits for uranium after inhalation by workers and the public,” 105 *Radiation Protection Dosimetry* (2003) p. 176. Another reference states “The Annual Limit of Intake for uranium-238, for a member of the public, as specified by the International Committee for Radiological Protection, equates to breathing in a mass of approximately 8 mg of Depleted Uranium.” The Lord Gilbert, UK Ministry of Defense, letter to The Countess of Mar, 2 March 1998 (in author’s files).

[5] For brief exposures, the American Conference of Governmental Industrial Hygienists (ACGIH) set a short-term exposure limit (STEL) of 0.6 mg/m³ over a 15-minute period. At a breathing rate of 9.6 m³ per eight-hour working day, this equates to a recommended short-term limit on inhalation intake of 0.18 mg. U.S. Agency for Toxic Substances and Disease Registry (ATSDR), “Toxicological Profile for Uranium” (Washington, DC: US Public Health Service, September 1999) p. 9 (hereinafter, ATSDR Report). “The STEL (i.e. less than a 15 minute exposure followed by periods of minimal or no exposure) would apply to the shorter-term exposures occurring in the Gulf War (e.g., entering damaged equipment).” The Office of the Special Assistant to the Deputy Secretary of Defense for Gulf War Illnesses, Depleted Uranium in the Gulf (II) (Washington, DC, 2000) p. 19.

[6] Based on an 8-hour workday, 40-hour workweek maximum air concentration limit of 0.2 mg/m³, with an average breathing rate of 9.6 m³ per 8-hour working day. U.S. Agency for Toxic Substances and Disease Registry (ATSDR), “Toxicological Profile for Uranium.” (Washington, DC: US Public Health Service, September 1999) pp. 322, 329. The 2 mg figure applies for both soluble (type F) and insoluble (type S) compounds; N. Stradling et al, “Anomalies between radiological and chemical limits for uranium after inhalation by workers and the public,” 105 *Radiation Protection Dosimetry* (2003) p. 177; Dr. Naomi Harley, statement to the Presidential Special Oversight Board for Department of Defense Investigations of Gulf War Chemical and Biological Incidents (Washington, D.C., 19 July 1999); The Office of the Special

Assistant to the Deputy Secretary of Defense for Gulf War Illnesses, Depleted Uranium in the Gulf (II) (Washington, DC, 2000) p. 18.

[7] US Code of Federal Regulations, 10 CFR 20, "Standards for Protection Against Radiation," Subpart C, 20.1201, "Occupational Dose Limits for Adults, 1 January 2001.

[8] The annual limit on inhalation intake is based on the volume of air that a worker is assumed to breathe in a year (2,400 m³), and the occupational exposure limit of 0.2 mg/m³. U.S. Agency for Toxic Substances and Disease Registry (ATSDR), "Toxicological Profile for Uranium." (Washington, DC: US Public Health Service, September 1999) pp. 321, 329; US Code of Federal Regulations (CFR), 29 CFR 1926.55, Appendix A, "Threshold Limit Values of Airborne Contaminants for Construction," Uranium, 1 July 2000.

[9] For brief inhalation exposures, the UK Health and Safety Executive (HSE) set a short-term exposure limit (STEL) of 0.6 mg/m³ over a 15-minute period. At a breathing rate of 9.6 m³, this equates to a recommended short-term limit on intake of 0.18 mg, based on chemical toxicity. UK Health and Safety Executive (HSE), *Occupational Health Exposure Limits 2000*, EH40/2000 (Sudbury, Suffolk, HSE Books 2000).

[10] This is the occupational exposure limit for soluble natural uranium compounds (0.2 mg/m³), at a breathing rate of 9.6 m³ per 8-hour working day, based on chemical toxicity. Ibid.

[11] This refers to an inhalation of type S (insoluble) natural uranium based on a 5 micron activity mean aerodynamic diameter. As noted above (see supra n. 8), the majority of DU particles created by an impact are insoluble. The limit for intake by inhalation of type M (moderately soluble) natural uranium is 430 mg/year; for type F (soluble) it is 1290 mg/year. N. Stradling et al, "Anomalies between radiological and chemical limits for uranium after inhalation by workers and the public," 105 *Radiation Protection Dosimetry* (2003) p. 176.

[12] The Royal Society, "The health hazards of depleted uranium munitions, Part I." (London: Royal Society, 2001) p. 5.

[13] Presidential Special Oversight Board for Department of Defense Investigations of Gulf War Chemical and Biological Incidents, "Special Oversight Board Analysis (Ver. 2) of OSAGWI"s DU Report," (Washington, DC, 19 February 1999) (in author's files).

[14] M.A. Parkhurst et al, "Depleted Uranium Aerosol Doses and Risks: Summary of U.S. Assessments," PNWD-3476 Prepared for the U.S. Army by Battelle (Richland, WA: Battelle, October 2004) http://www.deploymentlink.osd.mil/du_library/du_capstone/index.pdf.

[15] The Royal Society"s *central estimate* "is intended to be representative of the average individual within the group (or population) of people exposed in that situation." The Royal Society, "The health hazards of depleted uranium munitions, Part I." (London: Royal Society, 2001) pp. 6, 41-43. See also Annexe C of the Royal Society Report online at http://www.royalsoc.ac.uk/policy/du_c.pdf.

[16] "We calculated a "worst case" estimate using values at the upper end of the likely range, but not extreme theoretical possibilities. The aim is that it is unlikely that the value for any individual would exceed the worst case… If even the worst-case assessment for a scenario leads to small exposures, then there is little need to investigate more closely. If, however, the worst-case assessment for a scenario leads to significant exposures, it does not necessarily mean that such high exposures have occurred, or are likely to occur in a future battlefield, but that they might have occurred, or might occur in future conflicts, and further information and assessment are needed." The Royal Society, "The health hazards of depleted uranium munitions, Part I." (London: Royal Society, 2001) pp. 6, 41-43.

[17] M.A. Parkhurst et al, "Depleted Uranium Aerosol Doses and Risks: Summary of U.S. Assessments," PNWD-3476 Prepared for the U.S. Army by Battelle (Richland, WA: Battelle, October 2004) Chapters 3, 4.

[18] M.A. Parkhurst et al, "Depleted Uranium Aerosol Doses and Risks: Summary of U.S. Assessments," PNWD-3476 Prepared for the U.S. Army by Battelle (Richland, WA: Battelle, October 2004) Chapters 3, 4.

[19] A.C. Marshall, "An Analysis of Uranium Dispersal and Health Effects Using a Gulf War Case Study," Sandia Report SAND2005-4331, (Albuquerque, NM: Sandia National Laboratories, July 2005) p. 59-60.

[20] Ibid, pp 59-60.

[21] It is assumed that "soldiers spend 4 weeks in an area, starting from the time it is contaminated with 1 g m²DU; all the DU is respirable; and the soldiers" activities cause enhanced resuspension of the DU owing to normal heavy vehicle movements, but the soldiers are not undertaking digging, ploughing or clearance

operations." "The central estimate is based on UK-like conditions…." The Royal Society, "The health hazards of depleted uranium munitions, Part I." (London: Royal Society, 2001) p. 43, Annexe C.

[22] It is assumed that "soldiers spend 4 weeks in an area, starting from the time it is contaminated with 1 g m²DU; all the DU is respirable; and the soldiers" activities cause enhanced resuspension of the DU owing to normal heavy vehicle movements, but the soldiers are not undertaking digging, ploughing or clearance operations." "[T]he worst case [estimate] is based on arid, dusty conditions." The Royal Society, "The health hazards of depleted uranium munitions, Part I." (London: Royal Society, 2001) p. 43, Annexe C.

[23] Alexandra Miller et al, "Transformation of Human Osteoblast Cells to the Tumorigenic Phenotype by Depleted Uranium-Uranyl Chloride," *Environmental Health Perspectives* (1998) 106: 469.

[24] Ibid., p. 470.

[25] A.C. Miller et al, "Depleted uranium-catalyzed oxidative DNA damage: absence of significant alpha particle decay." 91 *Journal of Inorganic Biochemistry* (2002) p. 251; A.C. Miller et al, "Genomic instability in human osteoblast cells after exposure to depleted uranium: delayed lethality and micronuclei formation." 64 *Journal of Environmental Radioactivity* (2003) p. 248.

[26] A.C. Miller et al, "Depleted uranium-catalyzed oxidative DNA damage: absence of significant alpha particle decay." 91 *Journal of Inorganic Biochemistry* (2002) pp. 246, 251

[27] A.C. Miller et al, "Genomic instability in human osteoblast cells after exposure to depleted uranium: delayed lethality and micronuclei formation." 64 *Journal of Environmental Radioactivity* (2003) p. 257.

[28] A.C. Miller et al, "Depleted uranium-catalyzed oxidative DNA damage: absence of significant alpha particle decay." 91 *Journal of Inorganic Biochemistry* (2002) p. 251.

[29] In 1999 the incidence of Hodgkin's lymphoma among US residents was 2.8 per 100,000 people (3.0 for men, 2.5 for women). For men and women aged 25-29, the incidence was 5.4 per 100,000; for ages 30-34 the incidence was 4.1 per 100,000. L.A.G. Ries, M.P. Eisner, C.L. Kosary, B.F. Hankey, B.A. Miller, L. Clegg, B.K. Edwards, eds., *SEER Cancer Statistics Review, 1973-1999*, National Cancer Institute, Bethesda, MD,
http://seer.cancer.gov/csr/1973_1999/, 2002. Incidence rates in other countries with forces that served in the Gulf War or Balkans are similar: Italy – 3.62; The Netherlands – 2.32; United Kingdom – 2.26; Saudi Arabia – 2.69; Kuwait – 4.33; Iraq – 2.10. J. Ferlay, F. Bray, P. Pisani and D.M. Parkin, GLOBOCAN 2000: Cancer Incidence, Mortality and Prevalence Worldwide, Version 1.0, IARC CancerBase No. 5, Lyon, IARCPress, 2001, Limited version available from: URL: http://www-dep.iarc.fr/globocan/globocan.htm, last updated on 03/02/2001.

[30] U.S. National Cancer Institute, "Information about detection, symptoms, diagnosis, and treatment of Hodgkin's disease," NIH Publication No. 99-1555, 16 September 2002.

[31] US Institute of Medicine, Gulf War and Health, Volume 1, "Depleted Uranium, Pyridostigmine Bromide, Sarin, Vaccines." (Washington, D.C., National Academy Press 2000) p. 142.

[32] M. McDiarmid, et al, "Surveillance of Depleted Uranium Exposed Gulf War Veterans: Health Effects Observed in an Enlarged "Friendly Fire" Cohort," 43 *J Occup Environ Med* (2001) p. 998.

[33] See discussion of U.S. DU Program at end of Chapter 2.

[34] UK Ministry of Defence, "UK Gulf Veterans" Mortality Figures," August 2002.
http://www.mod.uk/issues/gulfwar/info/gen_reports/mortfigs_jun02.htm.

[35] Statement of Lewis Moonie, UK Defence Minister, in response to Dr. Gibson, House of Commons Hansard Written Answers for 11 February 2003, http://www.parliament.the-stationery-office.co.uk/pa/cm200203/cmhansrd/cm030211/text/30211w04.htm.

[36] Original in Italian: "*Esiste un eccesso, statisticamente significativo, di casi di Linfoma di Hodgkin.*" Istituita dal Ministro Della Difesa, "Relazione Finale Della Commissione Istituita dal Ministro Della Difesa Sull"Incidenza di Neoplasie Maligne Tra I Militari Impiegati in Bosnia e Kosovo," 11 June 2002, p. 21.

[37] Original in Italian*: "I risultati dell"indagine a campione svolta sui militari italiani impiegati in Bosnia e Kosovo non hanno evidenziato la presenza di contaminazione da uranio impoverito." Istituita dal Ministro Della Difesa, "Relazione Finale Della Commissione Istituita dal Ministro Della Difesa Sull"Incidenza di Neoplasie Maligne Tra I Militari Impiegati in Bosnia e Kosovo."* Ibid, p. 21.

[38] Original in Italian: "*Per le neoplasie maligne (ematologiche e non), considerate globalmente, emerge un numero di casiinferiore a quello atteso*." Ibid., p. 21. See also C. Nuccatelli et al, "Depleted uranium: possible health effects and experimental issues," 79 *Microchemical Journal* (2004) 332.